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Advancing Waste Reduction and Resource Conservation through Circular Economy Practices: A Rational Review

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Abstract

The modern world is undergoing profound changes due to globalisation, digital transformation and the depletion of natural resources; it requires radical modernisation of the economy and repeatedly involves introducing new organisational and economic models that combine economic development, environmental safety and the rational use of natural resources. To address these challenges, it is crucial to shift towards a sustainable lifestyle that balances short-term economic interests with long-term environmental impacts. As the foundation of the new industrial revolution, the circular economy offers a pathway to creating more competitive and sustainable economies where waste becomes a resource and economic development does not contradict environmental protection, but its implementation requires a comprehensive approach. This study aims to demonstrate the necessity of transitioning from a linear to a circular production model to minimize waste and conserve natural resources through the integrated application of cyclicality principles. This approach enables enterprises to achieve profitability while alleviating the strain on natural resources. Using a systematic approach and various scientific methods such as analysis, synthesis, deduction, generalisation, and abstraction, this review investigates modern environmental challenges and identifies one of our most significant environmental problems: waste minimisation and conservation of natural resources. The paper evaluates the potential and limitations of implementing the circular economy in contemporary economic contexts to enhance efficiency and safety. The critical indicators of the circular economy were analysed, allowing a general idea of the progress in this area in recent years, based on the example of the European Union. The study concludes that a successful transition to a circular economy requires a comprehensive approach that creates new business opportunities and promotes interaction between enterprises, society and the state, ensuring the exchange of experience and knowledge.

Keywords

Innovations; Sustainable development; Natural resources; Circular economy; Waste minimisation

Introduction

The crisis of natural resource depletion is one of humanity's most critical challenges in the 21st century. Economic development has triggered several acute problems, including global warming, resource scarcity and deepening social stratification. Irrational use of natural resources leads to environmental degradation and climate change, threatening the stability of our planet. The rate at which humanity depletes its resources will soon cross a critical threshold potentially leading to irreversible environmental disasters. The depletion of natural resources and environmental disasters prove that traditional production, consumption and waste disposal models have exhausted their viability and need to be radically reassessed.

The transition to a circular economy reduces dependence on finite natural resources, stimulates innovation, and creates a more resilient economy capable of withstanding global challenges. This innovative approach radically changes the outdated economic model by moving from a linear production-consumption-disposal system to a circular one, where resources circulate in a closed loop. The efficient use of resources in a circular economy contributes to environmental protection. It impels economic development and job creation, as companies can reduce their raw material and energy costs, increase competitiveness and create new business models (Korhonen *et al.*, 2018)

The European Union, as an example of successful implementation of the circular economy, invests heavily in its development, allocating hundreds of millions of euros annually (Ellen MacArthur Foundation, n.d.). This not only helps preserve natural resources but also creates the potential for economic prosperity without worsening the environmental situation (Atstaja *et al.*, 2022). Due to significant EU investments, the circular economy is becoming increasingly attractive to businesses, boosting the development of innovative solutions and employment growth while reducing the environmental burden.

Globally, other regions are also making strides in implementing circular economy principles. For instance, Japan has introduced comprehensive recycling and resource management policies, while China has incorporated circular strategies into its national development plans, focusing on industrial symbiosis and resource efficiency. However, despite progress in various regions, the shift to a circular economy remains a long and challenging process. The objectives of this research are to examine the current state of circular economy practices globally, identify key barriers to its implementation, and propose strategies to enhance waste reduction and resource conservation.

Literature Review

Scientific research aimed at developing sustainable management models that will preserve natural resources for future generations proves that this issue is crucial for the future of humanity. Research by Vergara and Jammi (2022) shows that soil, air and water pollution, clogging of storm drains and waste incineration, and the release of toxic substances into the air and water are severe environmental problems that result from improper waste management, threatening human health and the environment and leading to the degradation of natural ecosystems. In addition, it leads to socio-economic

problems, as noted by Fanning *et al.* (2021), namely significant inequalities in the distribution of wealth and resources within and between countries; many people are unable to meet their basic physiological needs; the rich consume significantly more resources than the poor, and thus contribute to environmental overconsumption. The study's findings by Winkler *et al.* (2021) highlight the need for urgent action to preserve the earth and its resources. They also point to the need to revise current land management strategies and develop new approaches that take into account more accurate estimates of land use change.

The analysis of the adverse effects of human impact on the environment has led the scientific community to conclude that traditional approaches to economic development need to be rethought, as Harpprecht *et al.* (2021) noted. This has spurred an active search for innovative solutions and contributed to the rapid development of new economic models to preserve the environment. The term "circular economy" first appeared in the 1990's work of British ecologists Pearce and Turner (1990). In the study "The Economics of Natural Resources and the Environment", the authors draw particular attention to the fact that the linear model of the economy, which involves the extraction of resources, production and disposal of waste, has led to the depletion of natural resources and the deterioration of ecosystems (Murray *et al.*, 2015). They propose an alternative approach – a circular economy, where materials are constantly circulating, and waste is minimised or wholly recycled, allowing for a more sustainable economy that does not harm the environment. Publications on the circular economy in the global scientific literature have a long history, associated with a long period of research and development of this economic model in the world's leading countries (Arsawan *et al.*, 2024; Atstaja *et al.*, 2022; Koval *et al.*, 2023). The active interest in this regard is that many countries have embarked on its implementation several decades ago, which stimulated relevant research. After analysing the theoretical foundations underlying sustainable development and the circular economy, Strapchuk (2020) concluded that the circular economy is a critical element of sustainable business 2.0 and a powerful incentive to rethink traditional approaches to business. According to Kirchherr *et al.* (2017), the circular economy is a business model based on the reuse of resources that combines economic efficiency, environmental sustainability and social justice. Geissdoerfer *et al.* (2017) describe the circular economy as a constantly renewed system that minimises resource consumption through reuse. We share the point of view of Haas *et al.* (2015), who define the circular economy as a strategy to minimise resource use and waste generation by creating closed loops.

Research shows that the “circular economy” concept is critical to launching recovery and regeneration processes in industry. Murray *et al.* (2015) emphasise that the circular economy involves careful planning and organisation of all stages of production and consumption to minimise waste and maximise resource efficiency. This concept is based on four main components: social and environmental responsibility, circular economy principles (R-principles), rational use of resources and promotion of recycling. However, in 2018, the World Economic Forum presented an updated model of the circular economy, which includes ten fundamental principles that contribute to more sustainable development: refuse to rethink, minimise, recycle, repair, restore, adapt to new use, recycle, and renew energy, compost (Schwab, 2018; Tymoshenko *et al.*, 2023).

Developed European countries are actively working to implement the principles of the circular economy, understanding their potential for sustainable development, being a leader in producing and exporting high-tech goods, consistently implementing policies to stimulate innovation and moving to a circular economy model. Studying the trends in the development of the circular economy noted that even with common European principles of the circular economy, their specific implementation in each EU country has its nuances due to national characteristics of the economy, culture and legislation Horbal *et al.* (2021). The European single market and the development of digital technologies create a favourable environment for implementing the circular economy, which will increase the competitiveness of the European industry and stimulate innovation (Roleders, 2023). Although the number of publications on the circular economy is considerable, the depth of understanding of the transition to this model requires further research, especially in the context of the current challenges of digitalisation, geopolitical changes and the increased level of militarization in the world.

The study aims to justify the need to move from a linear production model to a circular one to minimise waste and preserve natural resources by analysing the potential of the circular economy as an effective tool for solving global problems, which will allow businesses to make a profit while reducing the burden on natural resources. The study's main objective is to identify the key factors influencing the level of circular economy development in the EU countries and its advantages and disadvantages to justify a comprehensive model of interaction between governments, businesses, and the public for its successful implementation.

Methodology

This study uses a systematic review methodology to examine the impact of the circular economy on waste minimization and resource conservation. A systematic review was chosen because it allows for a structured synthesis of existing research, providing a comprehensive understanding of the topic.

A thorough literature search was conducted across multiple academic databases, including Scopus, Web of Science, and Google Scholar. Search terms included “circular economy”, “waste reduction”, and “resource conservation”. Peer-reviewed journal articles, reports, and conference proceedings published between 2015 and 2023 were included to ensure a current analysis. Articles were selected based on relevance, availability in English, and focus on empirical or theoretical aspects of the circular economy. Papers without a robust methodological foundation or those that focused exclusively on related issues, such as renewable energy, without addressing the principles of the circular economy were excluded.

The data obtained was systematically evaluated using thematic analysis to identify recurring patterns, strengths, weaknesses, and critical gaps in existing research. Systems analysis was applied to understand the relationship between waste accumulation, environmental pollution, and the implementation of circular economy strategies.

Results

Driving forces for developing a circular economy

One of today's most significant environmental challenges is minimising waste and preserving natural resources. Continuous population growth, urbanisation, industrial development and consumer lifestyles are driving factors behind this issue. Intensive human economic activity, enhanced by scientific and technological progress, leads to the degradation of natural ecosystems and the disruption of global ecological balance (Fanning *et al.*, 2021). Limited recycling services, improper landfill disposal, and harmful incineration practices stem from low environmental awareness.

Although some pollutants have declined significantly in their nature and source point, problems with harmful particles, nitrogen oxides, and sulphur dioxide exist, especially in cities with high transport and industrial activity (Harpprecht *et al.*, 2021). Pollution of surface and groundwater with nitrogen, phosphorus and other substances from agriculture and industry remains a significant concern. Climate change is exacerbating existing environmental problems by causing more frequent extreme weather events, sea level rise and biodiversity loss, and rapid industrialisation in developing countries is leading to increased emissions of greenhouse gases and other pollutants (Persson *et al.*, 2022). Despite recent downward trends in the European Union, the increased consumption and production of disposable goods continue to elevate greenhouse gas and air pollutant emissions, as well as pressure on natural resources (see Figure 1). Still, the consumption of raw materials remains almost unchanged.

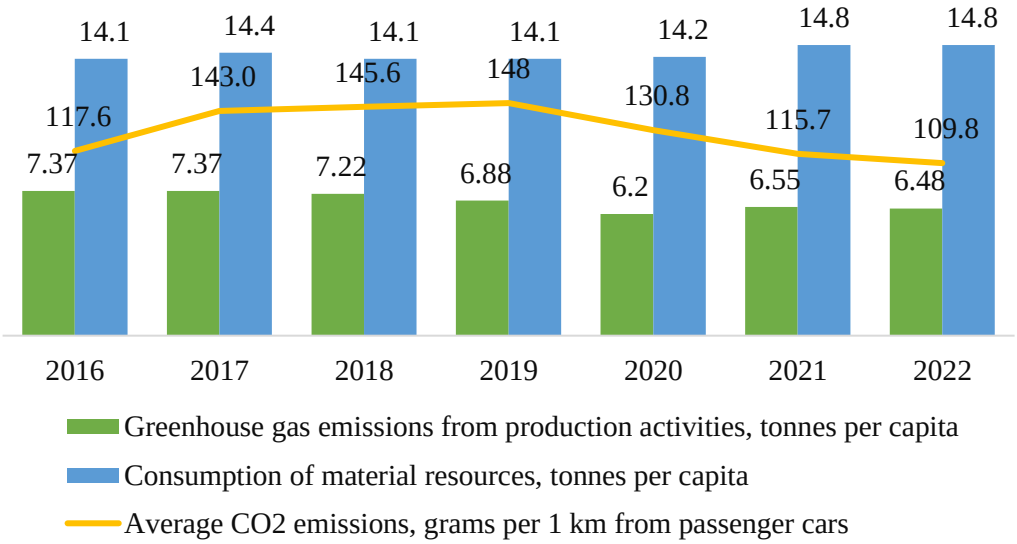

Figure 1: Consumption of material resources, greenhouse gas and air pollutant emissions in the EU countries in 2016–2022 (*Source:* Eurostat, n.d.)

The circular economy is a new paradigm that involves moving away from the traditional linear model of the economy and towards a model in which resources are used as efficiently as possible throughout the entire product life cycle. In a circular economy, products and materials are continuously circulated to retain their value for extended

periods. This approach optimises the use of natural resources and promotes their renewal, which helps to save resources and reduce damage to the ecosystem (Artyushok *et al.*, 2023; Horbal *et al.*, 2021). Through the circular economy, society can achieve a harmonious combination of economic growth and environmental sustainability, abandoning the traditional linear "take-make-use-discard" model used in the past.

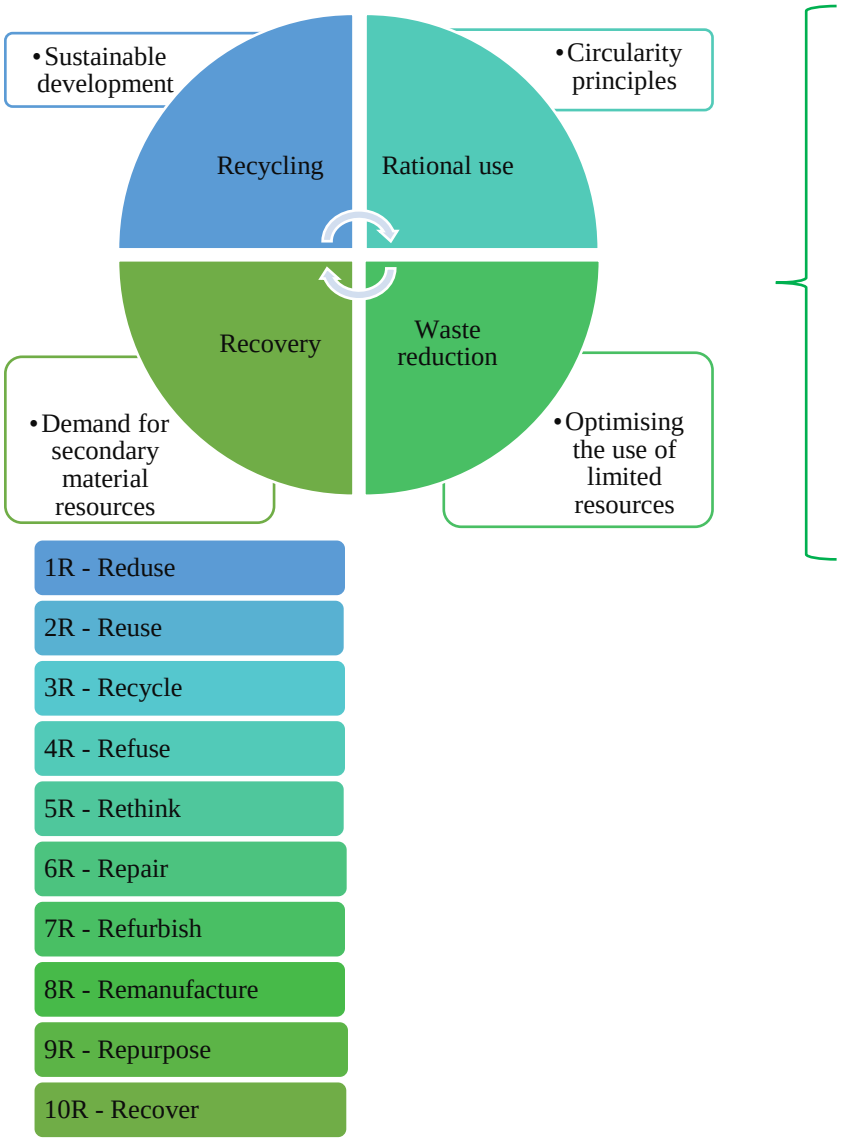

Figure 2: A comprehensive model for implementing the circular economy (*Source:* Cobirzan *et al.*, 2023)

The concept of circular economy merges the best ideas from diverse fields, including ecological economics and sustainable development theory (Boulding, 1966). The main objective of the circular economy is to reduce the ecological footprint through the rational use of resources. As a closed-loop structure, the circular economy redefines traditional economic models by converting waste into valuable resources. The circular

economy is a desirable goal, but achieving it in full may be extended. It should be rephrased even partially implementing its principles can bring significant results (Korhonen *et al.*, 2018a; Korhonen *et al.*, 2018b; Reike *et al.*, 2018). We believe that any economic system can progress towards circularity by gradually introducing its principles. Instead of the linear extraction-production-consumption-disposal scheme, the circular economy creates a closed loop where resources are constantly circulated, reducing waste to an absolute minimum through rational use (Figure 2).

The European Union has set a global example of successful adaptation to the circular model, actively developing the theoretical foundations and practical tools for its implementation. Various financial instruments have been introduced, such as grants, loans, capital investment guarantees, and programmes to support businesses implementing circular solutions, funded by various agencies such as the EU Regional Development Fund (ERDF), the Cohesion Fund by various agencies, and the Horizon Europe Programme. These instruments aim to foster the emergence and development of new ideas, technologies and business approaches and help companies overcome financial barriers to circularity (CGR, 2023; Kirchherr *et al.*, 2018). Through a comprehensive approach that combines policy, investment and cooperation, the EU has achieved significant results in reducing waste, increasing recycling and energy efficiency and stimulating innovation in these areas (Figures 3 and 4). Optimisation of production processes with new technologies could reduce industrial raw material consumption by 17-24% by 2030 (BMZ, 2023), potentially saving businesses €630 billion annually (Venturini, 2021).

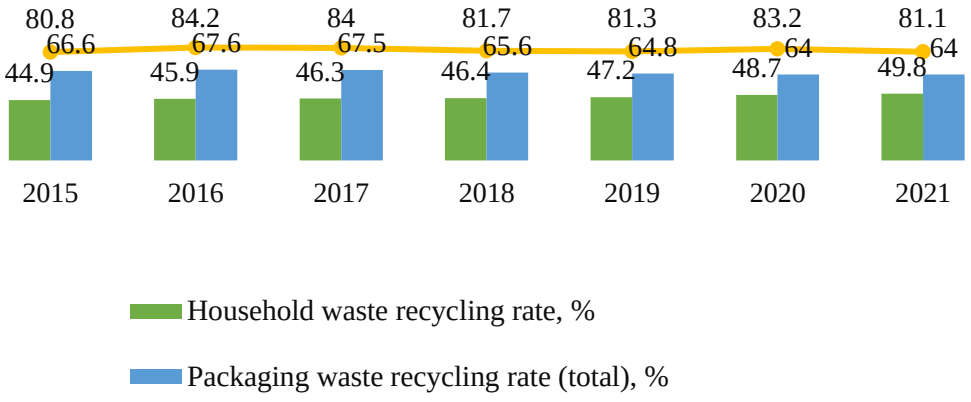

Figure 3: Dynamics of waste management and innovation indicators in the EU circular economy in 2015–2021 (*Source:* Eurostat, n.d.)

The circular economy establishes closed loops for products, materials, and energy, enabling economic development without depleting resources. The 10R model highlights the gradual shift towards a zero-waste economy, beginning with basic strategies such as waste reduction and gradually introducing more sophisticated approaches such as reuse and recycling (Venturini, 2021). Recycling is based on the principle of "best to worst": first, high-value products are created, and then, if this is not possible, waste is used to generate energy (Murray *et al.*, 2015; Salvador *et al.*, 2020).

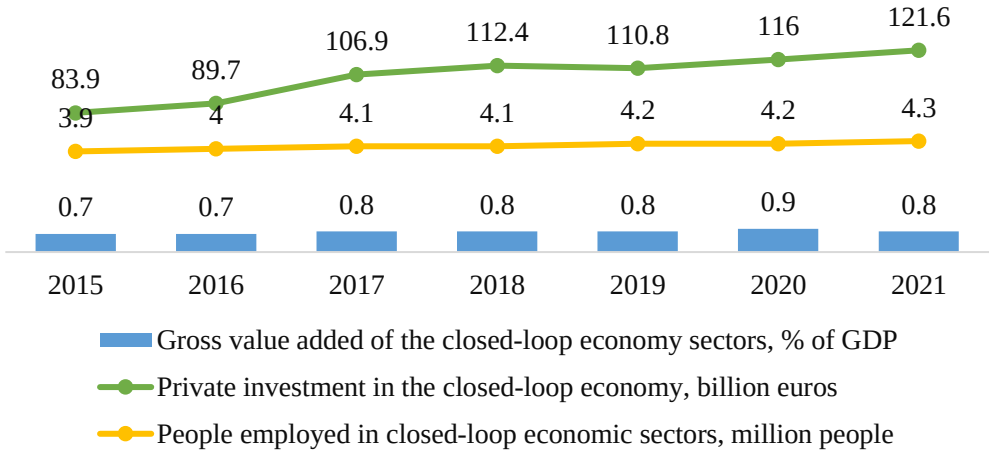

Figure 4: Dynamics of competitiveness and innovation indicators in the circular economy of the European Union countries in 2015–2021 (*Source:* Eurostat, n.d.)

The uniqueness of the circular economy lies in internal mechanisms that can independently stimulate its development and remove obstacles that arise along the way. Each element facilitating the transition to a circular economy influences overcoming barriers and the successful implementation of strategies (Ritzén and Sandström, 2017; Schöggl *et al.*, 2020). For example, product design determines these strategies' cost-effectiveness, scalability and quality. By transitioning from product sales to creating value, companies are adopting models centred on providing services and supporting the product lifecycle, thereby increasing revenue and strengthening customer relationships. Like any other system, the circular economy has its advantages and disadvantages, as shown in table 1, so it is essential to understand them to make informed decisions about its implementation.

Table 1: Advantages and disadvantages of the circular economy

Benefits of a circular economy	*Disadvantages of a circular economy*
−Conservation of natural resources. The circular economy helps conserve natural resources and reduce environmental pressure by reusing materials and minimising waste. −Reducing greenhouse gas emissions. Recycling and reusing materials requires less energy than producing new products from virgin raw materials, which leads to lower greenhouse gas emissions. −Creation of new jobs. The transition to a circular economy stimulates the development of new technologies and business models, which creates new	−High initial investment. Transitioning to a circular economy requires significant investment in new technologies, infrastructure and staff retraining. −Difficulty of implementation. Implementing a circular economy requires a change in thinking and action at all levels, from producers to consumers, which can be complex and time-consuming. −Inadequate infrastructure development. Many regions lack the necessary infrastructure for waste collection, sorting and recycling.

Benefits of a circular economy	*Disadvantages of a circular economy*
jobs in sectors such as recycling, repair, and product development. – Increased competitiveness. Companies that implement circular economy principles can reduce their raw material costs, increase production efficiency and create new products that meet the needs of modern consumers. – Strengthening the economy. A circular economy can contribute to more sustainable economic growth by reducing dependence on commodity price fluctuations and ensuring more stable supply chains.	– Lack of standards and regulations. A lack of standards and regulations can make it challenging to implement a circular economy. – Difficulty in assessing effectiveness. Evaluating the effectiveness of circular projects can be difficult due to the lack of standard methodologies and indicators.

Source: Cherevko (2022)

The circular economy is a promising model for addressing many global issues, but its successful implementation necessitates collaboration among governments, businesses, and the public (Figure 5), alongside significant investments in research, development and infrastructure (Bocken and Ritala, 2021). In addition, it is giving rise to new business models such as sharing, renting, repairing and recycling, which creates new business opportunities and fosters cooperation between different companies, academic institutions and NGOs, allowing for the exchange of knowledge and experience, where each party has its roles and responsibilities. The complete transformation of the economy to a circular model is indeed an ambitious goal that requires a comprehensive and coordinated approach from all stakeholders, but further efforts and cooperation of all stakeholders are needed to achieve a sustainable effect in the following areas (Ometto *et al.*, 2024; Sillanpää and Ncibi, 2019; Tan *et al*., 2022):

- jointly defining goals and priorities to develop joint strategies and action plans that take into account the interests of all parties and contribute to the achievement of long-term sustainable development goals;
- developing an effective waste management system to create infrastructure for waste collection, sorting and recycling; developing incentives for separate waste collection;
- supporting innovation by creating a favourable environment for the development of innovative technologies and business models related to the circular economy;
- educational and training activities as part of information campaigns to raise public awareness of the principles of the circular economy, as well as the inclusion of sustainable development topics in the educational programmes of higher education institutions;
- creating spatial platforms for dialogue, such as forums, conferences and other events to share experiences and best practices;
- creating circular economy clusters within associations of enterprises, research institutions, universities and local governments to develop and implement joint projects;

- developing standards and certification to unify standards for products and services that meet the principles of the circular economy;
- creating markets for secondary resources and conditions for their efficient functioning, which will stimulate recycling and reuse of used products;
- Providing financial and advisory support to businesses transitioning to circular business models.

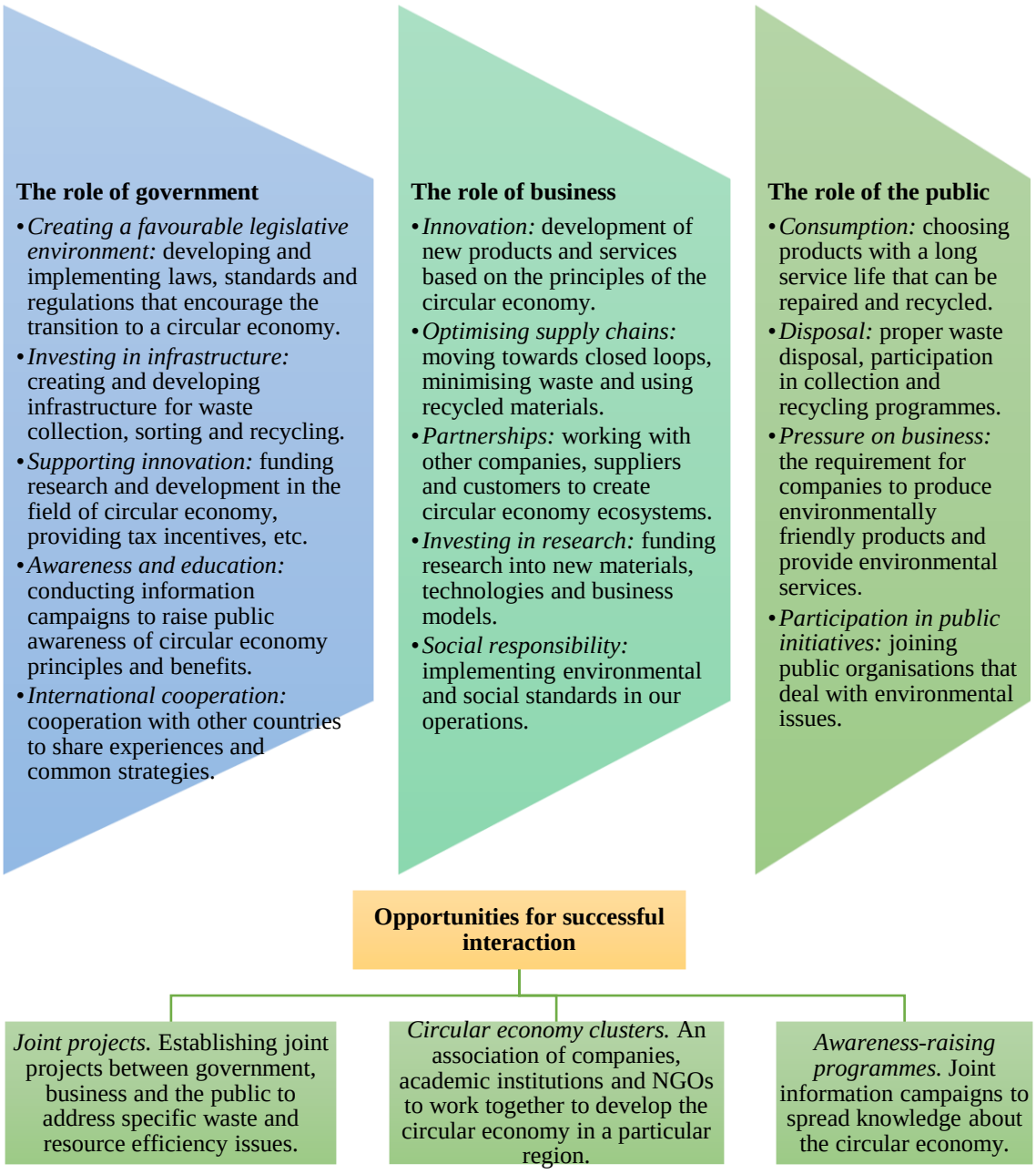
The role of government
•Creating a favourable legislative environment: developing and implementing laws, standards and regulations that encourage the transition to a circular economy.
•Investing in infrastructure: creating and developing infrastructure for waste collection, sorting and recycling.
•Supporting innovation: funding research and development in the field of circular economy, providing tax incentives, etc.
•Awareness and education: conducting information campaigns to raise public awareness of circular economy principles and benefits.
•International cooperation: cooperation with other countries to share experiences and common strategies.
The role of business
•Innovation: development of new products and services based on the principles of the circular economy.
•Optimising supply chains: moving towards closed loops, minimising waste and using recycled materials.
•Partnerships: working with other companies, suppliers and customers to create circular economy ecosystems.
•Investing in research: funding research into new materials, technologies and business models.
•Social responsibility: implementing environmental and social standards in our operations.
The role of the public
•Consumption: choosing products with a long service life that can be repaired and recycled.
•Disposal: proper waste disposal, participation in collection and recycling programmes.
•Pressure on business: the requirement for companies to produce environmentally friendly products and provide environmental services.
•Participation in public initiatives: joining public organisations that deal with environmental issues.
Opportunities for successful interaction
Joint projects. Establishing joint projects between government, business and the public to address specific waste and resource efficiency issues.
Circular economy clusters. An association of companies, academic institutions and NGOs to work together to develop the circular economy in a particular region.
Awareness-raising programmes. Joint information campaigns to spread knowledge about the circular economy.

Figure 5: Interaction between governments, businesses and the public for the successful implementation of the circular economy

The circular economy has a multilayered structure, founded on essential components and complemented by active elements that drive its development. In addition, an integral part of this structure is the social component, which ensures a fair distribution of resources and opportunities. Due to these components, the circular economy will become more accessible and attractive to various economic sectors, accelerating its spread (Jonker *et al.*, 2022). The proposed components can serve as a basis for developing national programmes and individual strategies of individual companies, allowing for the coherence of actions at different levels. The model based on these components can be scaled up and applied to developing national strategies for the transition to a circular economy and creating corporate sustainability plans.

Discussion

This study highlights the critical role of the circular economy in mitigating environmental challenges arising from rapid technospheric development and anthropogenic pressure. The findings indicate that adopting circular economy principles — such as waste reduction, resource conservation, and improved recycling practices — can significantly enhance environmental sustainability. Key insights reveal that integrating circular systems into industries and communities fosters ecosystem resilience and reduces biodiversity loss, aligning with broader climate goals. However, the methodological limitations of this study should be acknowledged. The analysis predominantly relies on secondary data sources, which may introduce biases due to variability in data collection methodologies. Additionally, the scope of the study is constrained to general global trends, which might not fully capture regional variations in the adoption and impact of circular economy practices. Future research should focus on longitudinal studies and incorporate more localized data to provide deeper insights into specific geographical contexts.

The rapid pace of technospheric development, driven by anthropogenic activities, continues to threaten the natural mechanisms of biosphere self-healing. This disruption is evidenced by climate change, biodiversity loss, and ecosystem degradation. Society's lack of environmental awareness, reflected in inadequate waste sorting and recycling practices, further exacerbates these challenges (Persson *et al.*, 2022). To address these issues effectively, transitioning from a linear sustainable development model to a circular economy is imperative.

The European Union countries are among the leaders in implementing circular economy principles today, making significant efforts to improve the environment and transition to a more sustainable economy. This approach has become a strategic goal for the EU, integrating the economic, social, and environmental aspects of sustainable development (Roleders, 2023). The fruitful work has resulted in the adoption of several directives and regulations that stimulate the transition to a circular economy, including the Waste Directive, the Packaging and repeating Waste Directive, the Ecodesign Regulation, the Extended Producer Responsibility (EPR) Principle, the EU Plastic Strategy (Bocken and Ritala, 2021). Significant funds are being allocated for research, development, and investment in projects related to the circular economy and active cooperation with member states, businesses, academia, and the public. Producer responsibility has been expanded, waste sorting and recycling has been encouraged, eco-friendly product design

requirements have been set to facilitate their repair, reuse and recycling, energy-efficient solutions in construction, industry, and households have been promoted, a second-generation biofuel market has been created, and the bioeconomy is actively developing (Salvador *et al*., 2020).

Although the circular economy is not aimed at maximising GDP as much as sustainable development, it can still significantly accelerate economic growth through several positive effects, such as reduced dependence on scarce resources and increased productivity. Its potential lies in reducing the risks associated with resource scarcity and environmental pollution. However, it is often underestimated, and most analyses do not consider how the circular economy can significantly reduce environmental restoration costs. Fluctuations in the prices of non-renewable resources result from the interaction of factors such as the development of extraction technologies, the depletion of easily accessible deposits, optimal extraction volumes and growing resource scarcity.

Externalities are one of the main barriers to an effective transition to a circular economy, but introducing appropriate policies, such as tax incentives and regulatory measures, can significantly reduce their impact (Bocken and Ritala, 2021). For example, an increase in taxes on the extraction of primary raw materials combined with a reduction in corporate taxes can encourage companies to use resources more efficiently without negative consequences for the state budget in the short term and even contribute to economic growth in the long term. Ignoring the environmental impact of economic activity leads to the depletion of natural resources and environmental pollution. Adopting a circular economy can mitigate this negative impact while maintaining economic growth.

The transition to a circular economy has become a global trend, with many countries actively implementing various initiatives to achieve this goal. The EU has devised an ambitious action plan to position Europe as a global leader in the circular economy. This plan encompasses a broad range of measures, including setting targets for waste reduction, promoting innovation and investment in the circular economy, and harmonising legislation. Many EU countries have introduced bans on using certain types of single-use plastics, such as plastic bags, disposable cutlery, and tableware, which helps reduce plastic pollution and encourages more eco-friendly alternatives.

Many US states are developing programmes and laws to advance the circular economy. For instance, certain states are implementing deposit return systems for bottles and cans, to promote recycling. A law passed in 2021 provides for significant investments in infrastructure, including recycling and waste disposal programmes, aimed at creating new jobs and stimulating the growth of the circular economy in the US. China is heavily investing in developing a circular economy, particularly in the waste recycling and green product manufacturing sectors, and is developing national standards for the circular economy while supporting innovative projects in this field. Japan has a long history of implementing resource conservation and waste recycling measures and continues to advance these initiatives, mainly through adopting new technologies and promoting circular economy development across various sectors.

Canada is actively developing a national circular economy strategy, including measures to reduce waste, promote innovation, and raise public awareness. Australia has

developed a national waste management plan, significantly reducing the waste sent to landfills. Despite different approaches, a joint global trend towards the development of the circular economy is evident: governments are investing in research and developing new technologies for waste recycling, producing environmentally friendly products, and creating more efficient resource management systems. They also work with businesses to develop and implement new business models based on circular economy principles. They are running public awareness campaigns to emphasize the importance of the circular economy and promote changes in consumer behaviour.

Conclusion

The transition from a linear to a circular economy represents a transformative approach to addressing pressing environmental challenges, including waste reduction, resource conservation, and ecosystem preservation. This study demonstrates that adopting circular economy principles not only fosters economic sustainability but also promotes environmental resilience by minimizing resource depletion and pollution. The analysis highlights the potential of circular systems to redefine traditional production and consumption models, shifting towards closed-loop processes where resources are reused and recycled effectively. European Union policies and initiatives exemplify the successful integration of these principles, showcasing the importance of a comprehensive approach involving financial incentives, innovative technologies, and collaborative frameworks.

Key recommendations for advancing the circular economy include:

1. Collaboration among governments, businesses, and communities to establish cohesive strategies that align with sustainable development goals.
2. Developing infrastructure for waste collection, sorting, and recycling, alongside incentives for responsible waste disposal.
3. Encouraging the development of technologies and business models that align with circular economy objectives.
4. Raising awareness and integrating sustainability topics into educational curricula to foster a culture of environmental responsibility.
5. Establishing forums, conferences, and circular economy clusters to facilitate experience sharing and joint project development.
6. Creating conditions that stimulate the recycling and reuse of materials through regulatory and financial support.

Although the transition to a fully circular economy remains an ambitious goal, gradual implementation of its principles can lead to significant environmental and economic benefits. The success of this transformation depends on the cooperation and commitment of all stakeholders, alongside sustained investment in research, infrastructure, and public engagement.

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Authors' Declarations and Essential Ethical Compliances

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Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	No	Yes	Yes	No
Collected the data	Yes	No	Yes	No	No
Contributed to data analysis & interpretation	Yes	Yes	No	Yes	No
Wrote the article/paper	Yes	Yes	No	No	No
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